ADVANCED MANUFACTURING

ABSTRACT

The Advanced Manufacturing Industry Study visited a wide range of manufacturing firms and met with domestic and foreign industry leaders from academic institutions, research and development organizations and various trade and labor associations. This paper assesses the state of advanced manufacturing by looking at the people, processes and technology that drive success in an industry sector critical to the United States' national security. Workforce demographics and skill levels are worldwide concerns occupying the attention of every company visited by the Advanced Manufacturing Industry Study. Process improvements that take advantage of information technology, and common sense approaches like lean manufacturing, increase efficiency and productivity. Research in leading edge technologies continues to promise exciting new manufacturing methods that will increase industry's flexibility and agility in rapidly delivering products to customers. However, some companies, for example defense contractors with low production rates, may not find it cost effective to adopt new technologies.

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Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **2002**	2. REPORT TYPE **N/A**	3. DATES COVERED **-**
4. TITLE AND SUBTITLE **2002 Industry Studies: Advanced Manufacturing**		5a. CONTRACT NUMBER
		5b. GRANT NUMBER
		5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER
		5e. TASK NUMBER
		5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **The Industrial College of the Armed Forces National Defense University Fort McNair Washington, DC 20319-5062**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S)
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release, distribution unlimited**		
13. SUPPLEMENTARY NOTES		
14. ABSTRACT		
15. SUBJECT TERMS		

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**UU**	**35**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

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INTRODUCTION. "Dirty, dull and dangerous." It is hard for manufacturing firms to compete for talent because of this smokestack stereotype. Although most of us were neophytes regarding advanced manufacturing, we expected to see wonders rather than drudgery. After all, this was *advanced* manufacturing. And in many respects our expectations were fulfilled. We saw chip fabrication lines - as antiseptic as operating rooms - whose life cycle is four years. We saw auto plants as clean as cafeterias where robots outnumbered human workers. So much for dirty. We repeatedly saw production runs of single units – from laptop computers to motorcycles. We also saw long production runs in process, but the trend was clearly toward rapidly reconfigurable production and shorter, customer-responsive runs. The dull stereotype is therefore also outdated. We saw plants where the latest technology is hand fitted in buildings that are not much altered from fifty years ago. So our preconceptions of what 'advanced' means were challenged, too.

Through a study of the wide range of domestic and foreign entities that make up advanced manufacturing, the Industry Study Group determined that, as a whole, manufacturing in the United States remains world class. Opportunities for increasing profit are deeply explored. The relentless way in which profit incentives drive technological innovation in the private manufacturing sector explains much of the widening gap between that sector and the defense sector, in the use of automation technology and best management practices. Enterprise resource planning, lean manufacturing practices, just-in-time inventory control models, and the outsourcing of non-core capabilities were commonplace in the firms visited. Reliance on web-based capabilities, some which link manufacturers with their customers and suppliers, and others uniting global networks of production units, was a notable trend.

Defense manufacturers were far behind the private sector due to low volume production, almost no competition, guaranteed profits and a stagnant workforce. Government support and attention to the defense sector is critical to maintaining a viable national defense.

September 11 changed the trajectory of our study in this academic year. We tried to examine the effects of the attack, and the subsequent Global War on Terrorism and reevaluation of national infrastructure assurance, on advanced manufacturing. It has been difficult to determine. We did not observe a mobilization. The entire U.S. economy was in a recession when the attacks occurred and the manufacturing sector had been experiencing decreasing employment well before the rest of the economy entered into recession. In response to our questioning, some firms stated that the September 11th attacks temporarily disrupted their supply chain and raised their sensitivity to the need to place additional emphasis on strategic reserves of critical supplies. However, even these firms were not taking any drastic measures or changing their processes in response to the attacks, or in anticipation of worse disruptions.

In Afghanistan, American technology enabled battlespace dominance. We examined industry research and development of future applications that will confer decisive advantage in force projection and C3I. Much of our report covers cutting edge technological innovation with future commercial and warfighting potential.

The War was also unprecedentedly engaged on the attacked home front, with the assurance of critical infrastructures. We examined the security of manufacturing, paying special attention to a reexamination of "just in time" supply. Does it proliferate vulnerabilities? Is the increased threat level driving industry toward stockpiling of materials and materiel, and away from pull supply facilitated by information technology (IT)? A team of students conducted a directed study of Enterprise Resource Planning (ERP), which is included in this report.

The attacks were preceded by a recession, which like all recessions had been heralded by a drop in manufacturing orders. Manufacturing indices had declined dramatically before the recession. Indices were reported up during our study, heralding the recession's possible end.

We examined systemic challenges confronting the manufacturing industry beyond the context of the business cycle. We synthesized many explanations for longer-term instability, including corporate myopia for short-term profits, and the overselling of IT valuation during the dot-com bubble.

As a result of our domestic and international visits, the Advanced Manufacturing Industry Study Seminar came away with an increased appreciation of the critical and complex nature of manufacturing, and an understanding that successful manufacturers integrate people, processes and technology to rapidly turn materials into finished products that address customer needs.

As problematic as manufacturing is, we report rapid consolidation of advances in materials, processing, management and information. We see renewed productivity and new marvels. That is the ascending baseline.

DEFINITION. The U.S. Census Bureau definition of manufacturing is "the mechanical, physical, or chemical transformation of materials and substances into new products."[i] We define advanced manufacturing as the insertion of new technology, improved processes, and management methods to improve the manufacturing of products.

Advanced Manufacturing at the Industrial College of the Armed Forces is a cross-cutting industry study that is applicable to any industry that produces a product. We have found that industries that concentrate on improving their processes using lean manufacturing techniques can accomplish advanced manufacturing with little or no investment in new technology. The process improvements themselves allow the manufacturer to make significant improvements in their efficiency and speed in delivering their product to their customers. Speed to market and speed in delivery to the customer are the standards for success in manufacturing today and almost all of the manufacturing improvements we saw were designed to cut time from the manufacturing process.

Advanced manufacturing is not an industry but a series of processes. At Sandia National Laboratories, where the most pure thinking has gone into such definitions, 'manufacturing' has been defined as "science and technology, process development and production, to make a

component and manage it through its life cycle," while their definition of 'advanced manufacturing' excludes 'production.' It's a reasonable research view. What's left?

- Materials organization
- Computational organization
- Research and development prototyping: Hardware, Models, Processes
- Process development, including unique production equipment

One could argue that science and technology plus process development is undeniably advanced but not (at least not necessarily) manufacturing. Laboratory researchers acknowledge the fact that what they mean by 'production' is traditional industrial 'manufacturing'. On the other hand, the third and fourth 'advanced' subcategories - prototyping and process development - can be accomplished on factory floors as well as in laboratories. Costs of such research can then more readily be recovered from revenues associated with products, leading to greater economic efficiency.

In the perspective of industrial consultants, what is 'advanced' has everything to do with production, but focuses outside of milling, joining and assembly processes traditionally associated with the term 'manufacturing'. In this view, 'advanced' manufacturing leverages information technology in the supply chain by generating an integrated approach toward supply chain 'synthesis' (vice 'management') oriented to developing positive 'flow' rather than 'links.' 'Warehousing' gives way to 'materials handling integration.'

Of course, from fabrication managers in high technology industries, one also hears that manufacturing applications and technology come down to the unchanging two basic components for production--people and materials.

CURRENT CONDITIONS. Advanced manufacturing occurs in many widely differentiated sectors of the economy. We observed manufacturing management and production practices in the auto, pharmaceutical, electronics and electrical equipment assembly, jet engine, construction equipment, and semiconductor sectors. In the defense sector, we observed manufacture of helicopters, munitions, aircraft and ships.

The behavior and strategy of the observed companies varied greatly. Some were clearly struggling to make any revenue and profit, while a few were expanding and producing at near capacity. Most were looking for new products or product differentiation, strategic alliances and partnerships, or novel marketing strategies to pull ahead in the current economy. Additionally, all were focused on cost-cutting efficiencies to improve their ability to compete. Such endeavors include out-sourcing or alternatively increased vertical integration, supply chain integration and Enterprise Resource Planning (ERP), and just-in-time and lean manufacturing.

Manufacturing currently accounts for 16% of U.S. Gross Domestic Product (GDP) and employs 14% of the nation's workers.[ii] From 1996-1999, manufacturing's percentage of GDP grew at a rate of 5.1%, while the economy as a whole grew at only 4.3% annually.[iii] Manufacturing accounted for 21% of the nation's total GDP growth during this period. Durable goods maintained a

6.8% average growth rate and the U.S. economy benefited by $1.8 trillion dollars in value added to the U.S. economy.[iv] Manufacturing, along with the non-manufacturing industries that are directly linked to manufacturing, accounts for approximately 45% of GDP and 41% of domestic employment.[v]

Manufacturing employment consists of almost entirely high-skill, technology-intensive jobs with wages well above the service sector. The notion of poorly educated blue-collar workers laboring in dangerous jobs in dank, smoke-belching factories is a bygone image. Reality is more likely to be clean rooms and pharmaceutical laboratories, and brightly lit, clean, environmentally friendly production facilities employing advanced automation, robotics, and information technology. This is particularly evident in companies' efforts to acquire both ISO 9000 (quality) and 14000 (environmental) certifications. Today approximately 72% of U.S. exports are manufactured goods.[vi] Manufacturing leads all industry sectors with e-commerce shipments that account for 12% ($485 billion) of the total value of all manufacturing shipments.[vii]

In 2000, manufacturers performed 75% of U.S. R&D activities, while providing 66% of the funding.[viii] Many companies reduced R&D investments in 2001 due to the soft economy. However, a few recognized the opportunity by increasing investment in new technologies and facilities to be positioned for the recovery.

Recession and Unemployment. All manufacturing sectors were impacted by the on-going recession and post 9/11 events. A recession was officially declared in March 2001 following two consecutive quarters of negative growth. In the manufacturing industry, evidence of the slowdown had been apparent long before. Reduced revenues as a result of declining demand, excess inventory, and negative manpower adjustments had afflicted the industry since 1999. Manufacturing employment is now at its lowest level since 1962, at slightly less than 17 million jobs or 14% of the total U.S. workforce.[ix] According to the National Association of Manufacturers, the industry lost 1.7 million jobs between Jan 99 and Jan 02, a full 10 percent decline in employment.[x] Approximately 400,000 of these lay-offs occurred post 9/11.[xi] Employment since January has continued to drop. However, the rate of decline has slowed, giving reason for optimism for the remainder of 2002.

Productivity and Information Technology. Information technology and information management systems are credited with the strong economy-wide growth and high productivity (> 3% per annum) of the mid and late 1990s. High productivity was especially important to the manufacturing industry where it generally equated to lower unit costs in production, and therefore, increased revenues and profits. In fact, manufacturing productivity averaged a 4.3% growth rate over the period 1996-1999.[xii] Although productivity had fallen precipitously during 2000, data from the fourth quarter of 2001 and the first quarter of 2002 indicate that productivity is rebounding.

Availability of Skilled Labor. The majority of companies visited expressed concern with their ability to hire skilled labor. Given the recession, none noted any shortage of applicants. However, almost without exception they were frustrated by applicants' lack of specific skills required for their industry. Most stated that applicants lacked the mechanical aptitude, knowledge, and technical background in basic math and sciences to propel their company in this highly competitive globalized economy. In the case of defense companies, the pool of qualified applicants was further reduced by drug testing and security requirements. A few companies placed equal emphasis on an applicant's ability to perform in a team environment or

alternatively, with minimal supervision. Job tender statistics such as 2 in 30, 1 in 60 or even 1 in 100 were commonplace among the companies visited.

To address the skills shortage, many companies developed targeted education and training outreach programs to improve basic skills and enlarge the pool of potential applicants. Partnerships, to include internships, were developed with local high schools, trade schools, and colleges and universities to educate and train students for employment. In some cases, companies developed their own in-house training and certification programs for specific skills, such as welding and pipefitting. These companies screened initial applicants for "employability" and then placed them into in-house training programs prior to assigning them to a manufacturing activity. No statistics were offered to validate the success of these initiatives, nor was there any quantification of return on investment, but all felt these managerial practices were both necessary and profitable in terms of "growing" the basic employee skills for their industry.

Automation and Robotics. Many companies sought to mitigate manpower shortfalls while simultaneously improving productivity and reducing costs by increasing the levels of automation and robotics in their manufacturing processes. High-speed machine tools under computer numerical control (CNC) continue to revolutionize manufacturing. More capable bits and cutters, and multi-axial machines, allow machining of ever larger components without repositioning. Variability continues to drop and quality and labor productivity to rise. Linked by the web, quality can be remotely controlled, which leverages engineering expertise. We saw robotics commonly employed for repetitive tasks such as auto body welding. This did substantially reduce manpower requirements on the floor as one or a few employees could operate and oversee several robotic manufacturing cells. However, the remaining employees needed even greater technical knowledge and skill. Not only were they expected to set-up and oversee robotic cells, but in many cases they were the first line of maintenance should the robots break down or the line stop. Employees who were capable of meeting these new challenges became that much more valuable to the companies and in return, could command higher levels of compensation.

Aging Workforce. Many of the companies visited faced the related issue of an aging workforce. The situation was particularly acute in defense and unionized facilities. Managers at one defense aircraft company quoted the average age of their manufacturing workforce to be 55 years; those at a defense munitions plant quoted their workforce at between 48-52 years. By contrast, those at a commercial, non-union semiconductor facility estimated their manufacturing workforce to be between 26-30 years.

The effects of aging are compounded when companies outsource their personnel surge requirements. U.S. firms often obtain surge workers as temps through manpower companies. In Japan, expatriate third generation Japanese descendents, recruited abroad for the purpose, can fill the gap. In both systems, a cohort of young, second-class workers are cycled in and out, and trained, yet are not expected to count on a career, advancement, or even a permanent position.

An aging workforce is a very experienced and skilled group of employees with comparatively higher levels of pay and benefits. This two-edged sword engenders higher relative levels of productivity with concomitant higher direct labor costs. An even greater concern is that their knowledge will be lost when they retire. Without the ability to systematically transfer knowledge to younger employees and facing the difficulty in hiring skilled labor, these companies may soon be facing a shortfall in their manufacturing capabilities.

All of this places a fundamental limitation on a company's ability to surge production. Most of the companies visited had significant excess capacity with facilities that could accommodate expanded production if required. However, to surge with a new manufacturing line or extra shifts would require an increase in manufacturing personnel which for the reasons cited above would not appear practicable in the short term.

CHALLENGES AND RESPONSES. U.S. manufacturers need to address several challenges in order to maintain competitive advantage. Adapting to the increasing effects of globalization and commercializing advanced technology requires constant fine-tuning. Adaptability is the key to generating and sustaining a competitive advantage in a global market. "Manufacturing in the information age will bring new ideas and innovations to the marketplace rapidly and effectively. Individuals and teams will learn new skills rapidly because of advanced network-based learning, computer-based communication across extended enterprises, enhanced communications between people and machines, and improvements in the transaction and alliance infrastructure."[xiii]

The National Research Council (NRC) report from which this quote is drawn noted several grand challenges to the future of advanced manufacturing, which we used as a baseline for our study.[xiv] The following paragraphs discuss our view of the challenges facing advanced manufacturing based on our domestic and international travel. In this new age, one key to the success of an advanced manufacturing firm is the ability of its senior leadership to leverage information to maintain a competitive advantage.

Concurrency. The first challenge is to achieve concurrency in all operations. That is, manufacturers should plan, develop, and implement in parallel, vice sequentially. Concurrent processing will bring together all elements of a product process from "cradle-to-grave." Increased use of networked processes and equipment will be required to transfer information and experience. This will make it possible to reduce product time to market, promote innovation, and improve quality. In order to meet this challenge and realize these improvements, U.S. manufacturing industries should address several items:

(1) *Development or purchase of intelligent collaboration systems*. Information sharing is the biggest priority if companies want to plan, develop, and implement in parallel. Without real-time information flow, successful concurrency is not possible. Collaboration hardware and software is an enabling tool to meet this challenge.

(2) *Identification and acquisition of technologies to convert information into knowledge for effective decision-making*. The vast quantities of information available now and in the future are becoming overwhelming for decision makers. Firms should use technology to assist in converting information to knowledge for management use.

(3) *System synthesis, modeling, and simulation for all manufacturing operations should be accomplished*. In order to achieve concurrency, it is necessary for all operations to peacefully coexist and to share information on a timely and accurate basis. However, some tradeoffs may have to occur. Understanding each system process and being able to model and simulate the process allows for understanding the existing complex interactions. Use of models and simulations would allow management to try new proposed operations to improve efficiency and competitive advantage.

(4) *System development to provide the ability to achieve concurrency (once the processes and interactions between them are understood).* Companies should identify, develop, and/or acquire adaptable, readily reconfigurable, integrated equipment, processes, and systems. Flexibility will be the key to maintaining competitive advantage in the future for advanced manufacturers. Flexible systems and processes, designed for rapid change, will provide advanced manufacturers the edge they need to rapidly respond to a changing market while maintaining concurrency in their processes.

Human/Technical Integration. A second challenge is to integrate human and technical resources to enhance workforce performance and satisfaction. Even though technology is rapidly improving and automation is becoming increasingly popular, firms cannot fully remove humans from manufacturing. During both domestic and international company visits, we saw that humans still do some tasks that machines cannot (usually that require specific dexterity), while machines handled tasks that humans cannot (movement of heavy objects – although usually with human guidance). However, we also viewed several processes where humans performed routine and often repetitive tasks where the use of technical resources could have improved the process. Therefore, better integration of human and technical resources is necessary to further improve manufacturing operations. In order to meet this challenge, manufacturers should address:

(1) *Development and/or acquisition of intelligent collaboration systems.* Similar to the concurrency challenge, information sharing is the biggest priority. Without real-time information flow, successful human-technical integration is not possible. Collaboration hardware and software is an enabling tool to meet this challenge.

(2) *Identification and acquisition of technologies to convert information into knowledge for effective decision-making.* Both human and technological systems require information to operate. Machines are becoming increasingly able to learn by action. Providing a capability for both human and machine to convert information to knowledge will provide tremendous benefits to the company.

(3) *Synthesis, modeling, and simulation of human-machine interfaces for all manufacturing operations*. Once a firm defines, models, and simulates tasks, they can develop various options for improving the human-technical interface. The models and simulations allow for evaluating those options for determination of whether human or technological improvements are the best solution.

(4) *Development of new educational and training methods to enable rapid assimilation of knowledge*. As previously stated, the quantity of information available to workers is increasing tremendously. However, we constantly heard that industry has been hard-hit to find labor with the required knowledge and skills. For example, owing to the need for specific knowledge and skills, the semiconductor industry has thousands of jobs that are going unfilled.[xv] Workers must be educated and trained to use information systems in order to rapidly assimilate information and transform it into useful knowledge. Industry must take on this challenge to educate and train, or there will be an increasing shortage of qualified workers.

(5) *Knowledge transfer from an aging work force.* One of the recurring trends encountered during our industry visits was the increasing age of the workforce. As noted above, some companies

had average workforce ages of over 55 years old. As these older workers finally retire, the loss of knowledge could be high. The manufacturing industry must anticipate this occurrence, and take action to retrieve that knowledge from the older workers and transfer it to a younger work force when required.

Information into Knowledge. Advanced manufacturers are dependent on information technology already, and will become more so in the future. This third challenge addresses the need to value, capture, and "instantaneously" transform information gathered from a vast array of diverse sources into useful knowledge for making effective decisions. For organizations to be truly successful in the information era and maintain their competitive advantage, they will have to learn how to "develop knowledge, procure knowledge, protect knowledge, and manage people with knowledge."[xvi] In order to accomplish this, manufacturers should provide for:

(1) *Synthesis, modeling, and simulation for all manufacturing operations.* Once a firm understands all operations and models them, effects of changes to any process or operation can be easily determined and disseminated quickly to all users.

(2) *Identification and acquisition of technologies to convert information into knowledge for effective decision-making.* As seen by the overwhelming effects of electronic mail on some workers, workers need technology to help deal with the vast amounts of information now available to them. Management must identify technology to collate information from different sources, deconflict that information, and transform it into knowledge useful to a company's workers.

(3) *Development of new educational and training methods that enable the rapid assimilation of knowledge.* Once a firm uses technology to transform information into knowledge, workers must be educated and trained to rapidly respond to what this tells them. That is, the workers need to be educated and trained on how to act rapidly on the knowledge transferred to them in order to take advantage of the technology. If workers cannot react rapidly, the investment in the technology may be wasted.

Rapidly Reconfigurable Systems. A fourth challenge to advanced manufacturing is to design, develop, and implement reconfigurable manufacturing enterprises to rapidly respond to changing needs and opportunities. The globalized marketplace changes rapidly. Manufacturers must be able to quickly and efficiently reconfigure their products and processes to take advantage of the changing marketplace and attain or maintain their competitive advantage. In order to do this, manufacturers should address:

(1) *Synthesis, modeling, and simulation for all manufacturing operations.* Once a company understands and models all operations, effects of changes to any process or operation can be quickly and easily determined. When operations must change, companies can use the models and simulations to determine the optimum reconfiguration for the new process.

(2) *Design, development and acquisition of readily reconfigurable, adaptable, and integrated equipment, processes,*

and systems. Rapidly changing customer needs, market opportunities, and information technologies drive the need for a company to be able to rapidly reconfigure and respond to changes. It is too costly in terms of both time and money to develop, design, and acquire new equipment, processes, and systems for every change. However, as seen during our industry visits, particularly to machine tool manufacturers, systems and equipment now exist that firms use interchangeably in a process. Flexible fixturing is one example of where interconnected equipment can be rapidly changed out (mixed and matched) to accommodate changing requirements. This equipment can then be immediately reprogrammed via its connectivity to the other machines and be fully ready for the new task.

Environmental. Manufacturing of products generally requires transforming of raw materials into some intermediate or finished product. This process also typically produces some form and quantity of waste. With the growing world population and increase in manufacturing products, the strain on the global ecosystem is increasing. Therefore, reduction of production waste and minimization of product environmental impact to "near zero" are big long-term challenges for manufacturing. Manufacturers are striving to develop cost-effective, competitive products and processes that don't harm the environment. Recycling and reduction of waste were the two most often cited examples of process improvements during our industry visits. However, manufacturers still face significant environmental challenges and should address the following:

(1) *Synthesis, modeling, and simulation for all manufacturing operations.* Modeling of manufacturing processes would provide a cost-effective method on analyzing risks and benefits to the environment of possible process/product changes. A goal would be to create and maintain a database of useful and accurate environmental assessments. This database could prove useful and cost-beneficial for further product/process developments as well as for regulatory defense.

(2) *Production with Near-Zero Waste.* In order to manufacture products with near-zero waste, it will be necessary to understand the product process from "cradle-to-grave." Only after understanding the entire process can an environmental evaluation be truly creditable. Manufacturers should consider use of advanced technologies in recycling and waste production. Additionally, recycling should be addressed to the maximum extent. The most environmentally successful firms visited were those who had developed recycling programs to use their production waste as resource materials for additional products and processes. The most common application was the use of production waste for energy. This not only reduced required waste disposal, but also provided for reduction of energy consumption from outside sources.

(3) *Environmentally Friendly Production.* A growing trend among visited companies was for meeting ISO 14000 standards for environmental processes. Manufacturers with a environmentally

friendly attitude tend to make more efficient use of their resources through product waste re-use, recycling, and more efficient processes that reduce waste generation. One good example is the use of powdered-coat painting of parts. One particular company's use of powder-coating versus liquid painting of products reduced product waste from seventy-seven 55-gallon drums of hazardous waste per year to five 55-gallon drums of waste per year. Manufacturers with an environmentally friendly production process and attitude are more likely to have a competitive advantage over their competitors by reducing the environmental costs associated with their products.

OUTLOOK

Economic. Since 1969, "there have been six economic downturns in manufacturing that have lasted, on average, about 10 months. Output fell about 9 percent and employment declined 7.5 percent (employment declined by about 1.5 million) during the typical economic downturn."[xvii] One of the most interesting observations made is that every economic downturn since 1969 was preceded by a surge in energy prices. Examples include: the Arab oil embargo—1973, turmoil in the Middle East, Iranian revolution—1980s, Iraq's invasion of Kuwait—1990, and the energy price spike in 2000.

While all sectors of the economy are affected by rising energy costs, the manufacturing sector is particularly vulnerable to surges in energy costs. "Manufacturing makes up 28 percent of the nation's overall energy demand, more than any other sector."[xviii]

Fluctuations in oil and natural gas prices create serious challenges in U.S. manufacturing. One such challenge is the difficulty manufacturers face in adjusting pricing strategies to compensate for spikes in energy costs. This challenge generates a rippling effect for employment, overall production, and economic growth in general. The manufacturing sector will remain vulnerable to fluctuations in energy prices in the foreseeable future unless alternative, price-stable, forms of energy become available industry-wide.

"Globalization has greatly increased the range and intensity of international political, economic, and social interactions." [xix] Generally speaking, manufacturers are more connected to the international economy than the rest of the U.S. economy—65 percent of U.S. manufacturing output produced in 1999 was for international trade. This is significant in that if the U.S. dollar is strong, the price of U.S. exports in markets overseas will be more expensive, resulting in decreased international demand for U.S. output. "Manufacturing operates in a global marketplace where prices are determined by supply and demand relationships and firms are price takers, not price setters." [xx] This truism will have more severe ramifications in the future as more and more newly developed countries gain economic power.

"The nature of manufacturing enterprises will evolve in response to changes in the technological, political, and economic climate." [xxi] Most of the executives we spoke with during our visits would agree that companies providing goods and services to consumers in the future must continue to emphasize the relationship between quality, service, and price. This means that companies must continue pursuing innovative ways to customize products (being agile), reduce product delivery time, and reduce costs consistent with consumer expectations.

Human Resources. The manufacturing workforce will be as diverse as the global economy." [xxii] People will continue to play a vital role in shaping the future of manufacturing. Competition will be fierce globally and firms able to adapt to meet the rapidly changing needs of the market will prosper. "Expanding productivity growth in the U.S. economy will require workers with higher levels of skills and knowledge to keep pace with the rapid technological changes." [xxiii]

In the future, "sustaining competitive advantages will depend on a company's ability to value and capture practical know-how or knowledge." [xxiv] Capturing practical know-how involves capturing the constant parameters used to make decisions. This involves developing knowledge management systems that give a company's workforce a wide range of capabilities in their manufacturing sector. The primary issues with knowledge systems will be related to a firm's current and future capabilities. Knowledge management systems will be seen as methods of creating organizational synergy that cannot be easily duplicated by competitors.

Processes. The future of manufacturing is moving toward concurrent engineering. Manufacturing is different from other industries (for example, the service sector) in that, generally speaking, there is not a lot of personal contact between the consumer of the product and the people actually producing or assembling the product. And "despite the rapid growth of information technology, firms still spend more money on old-fashioned capital equipment, such as drills and welding machines, than they do on computers, telephones, and other information gadgets." [xxv] Information technology will have its biggest future impact for manufacturing in the areas of planning, developing, and organizing. Technological advances in these areas should generate sufficient efficiencies allowing companies to respond to consumer needs, while at the same time reducing production delivery time and costs.

GOVERNMENT GOALS AND ROLES. The health of the U.S. advanced manufacturing industry affects both the economic and military elements of national power, and is therefore a national security issue. Consequently, the U.S. Government should assume an appropriate role

supporting the stability and vitality of this industry. The government should establish and enforce manufacturing policies in three key areas that directly affect the health of the industry: promoting the availability of skilled labor, encouraging manufacturing process improvements, and stimulating the research and development technology base.

Success in manufacturing largely depends on the quality and skill of the workforce. A common concern expressed by managers of both domestic and international firms is the shortage of personnel trained in science and engineering disciplines. [xxvi] To ensure an adequate pool of science and engineering workers in the U.S., government policies need to provide better incentives for U.S. students to enter the science and engineering areas of study. Given that the U.S. must increase the skilled labor supply, several policies can help relieve the skilled labor shortage. More U.S. students simply must graduate from science and technology (S&T) programs. [xxvii] The government should provide targeted incentives such as tax breaks or interest-free loans to entice domestic students to seek S&T education and training. S&T education is an investment in human capital and is essential to the vitality of a networked economy. The government should work in close partnership with industry to identify emerging skills that merit targeted financial incentives. Furthermore, manufacturers should be rewarded for providing internships to science and engineering graduate students.Government policies should also encourage highly qualified foreign graduate students to stay in the U.S. after graduation. Immigration policies should provide more flexibility for U.S. industry to recruit the best and brightest from other nations. U.S. companies can help to identify and sponsor outstanding foreign undergraduate, graduate and doctoral students. Exemplary foreign students should be given preferred consideration for U.S. citizenship after graduation. The government would have several years prior to graduation to complete any required background checks on foreign students.[xxviii]

Another U.S. workforce issue is aging, particularly among union manufacturers. The aging trend will create a major knowledge and leadership void in the next decade as the workforce enters retirement. Young skilled workers are seeking employment in other industries. This demographic trend will make U.S. manufacturers more dependent on immigrants to supplement the shortage of domestic workers. To ensure the U.S. has a sufficient labor force, immigration policies need to provide U.S. firms with greater flexibility to draw from the global workforce.

Manufacturing process improvements enhance competitiveness, but they often require significant capital investments. Government policies should provide economic incentives to encourage these investments. Fiscal policies, such as tax breaks for efficient processes or faster capital equipment depreciation schedules, can energize companies to implement process improvements and capital upgrades. Promoting international free trade agreements also gives U.S. manufacturers the ability to leverage market forces to improve manufacturing posture. Potential leverage areas are foreign research and development (R&D) efforts and the available pool of well-trained, skilled workers overseas.

R&D is the fuel for technology innovation.[xxix] Since advanced research requires tremendous resources and time before yielding useful products, [xxx] only governments and large multinational companies have the financial resources to support meaningful advanced research. Government has the greatest influence in this area through policies that sponsor advanced research across a broad spectrum of science and technology areas. Organizations such as the National Institutes of Science and Technology (NIST), National Science Foundation (NSF), and Defense Advanced

Research Projects Agency (DARPA) should expand their efforts to develop advanced manufacturing processes.

One R&D area in need of government support is flexible manufacturing. Flexible manufacturing will enable the mass customization of products and create new market opportunities in the commercial sector. Flexible manufacturing processes can provide the U.S. advanced manufacturing sector with continued world leadership, while providing DoD with assured access to affordable, customized war fighting systems.

Clearly, the public sector should not allocate resources where the private sector is already investing. However, the government should promote efforts that are too expensive or too long term for any one company to attempt alone, but if available, would benefit the broader industry. Funding flexible processes that can provide the government assured access to commercial manufacturing lines to quickly meet wartime surge production needs is an appropriate use of public funds. Likewise, efforts that reduce barriers to entry and accelerate infrastructure growth are appropriate. Other R&D areas that hold promise and should receive government support are robotics, nanotechnology, and micro-electromechanical systems (MEMS).

CONCLUSION. The 2002 Advanced Manufacturing Industry Study found that the U.S. manufacturing industry in the private sector is world-class when compared with the international industries we visited. Defense industry, because of its protected status and low volume production, lags behind the private sector in cutting edge processes and technology. In the private sector, the search for innovative ways to manufacture products, cut costs and reduce design-to-end-user time is fueled by a desire to maximize profits. The innovations focus on three areas: people, processes and technology. These are areas of concern and opportunity - areas where firms see the potential to increase their productivity through processes like Enterprise Resource Planning, lean manufacturing and research and development, and to commercialize advanced technology to maintain competitive advantage in a globalized economy.

INDIVIDUAL ESSAYS

CORPORATE USE AND CONTROL OF INFORMATION by CDR David Meyr

Advanced manufacturers in America and around the world are dealing with the opportunities and problems of managing information flow within and between companies, industries and customers, and across corporate and international boundaries. Computer technology has accelerated the pace of business to the point where the successful integration of information technology (IT) into the manufacturing process can be equated with corporate survival. The Gartner Group estimates that just the business-to-business (B2B) portion of e-commerce alone will skyrocket from about $145 billion in 1999 to $7.3 trillion in 2004, accounting for seven percent of all sales transactions.[xxxi] Lawrence Gershwin, the CIA's National Intelligence Officer for Science and Technology said in a 2001 speech, "The networked global economy will be driven by rapid and largely unrestricted flows of information…"[xxxii]

In the forefront of the information systems revolution in advanced manufacturing is a highly customizable "system of systems", Enterprise Resource Planning, or ERP. ERP potentially provides instant access simultaneously to and from the factory floor, receiving dock, accounting, product design, management, and the customer. This creates almost as many problems as it solves, as ERP shatters many of the classical business paradigms of information control, admittance to the corporate main database, business planning, and employee empowerment.

The integrated ERP solution brings the back office together with the front office in order to deliver value-added products and services the full length of the value chain, spanning customers, suppliers, manufacturers, distributors and financial institutions.[xxxiii]

ERP has gained a large measure of notoriety for the huge costs associated with installation, training and integration of the system. In June 2000, Nestlé SA signed a much publicized $200 million contract with SAP—and threw in an additional $80 million for consulting and maintenance—to install an ERP system for its global enterprise.[xxxiv] Total Cost of Ownership (TCO) includes hardware, software, professional services (i.e., consultants) and internal staff costs. In a Meta Group study of 63 companies--including large, small and medium size companies in a range of industries--the average TCO was $15 million dollars (the highest was $300 million and the smallest was $400,000).[xxxv]

ROI can take an agonizingly long time, especially given the high costs. The same Meta Group study of 63 companies found that it took eight months after the new system was in to see any benefits. However, the median annual savings from the new ERP system were $1.6 million a year.[xxxvi]

Analysis. ERP's promise is to "…integrate all departments and functions across a company onto a single computer system that can serve all those departments particular needs."[xxxvii] This enables different departments to more easily share information and serve both the companies and the customer's needs better. Integrating the approach can have a tremendous payback. When a customer service representative takes an order, all the information needed to complete that order will be at her fingertips. The customer's order history and credit rating, the company's stock levels and stock shipping location, the shipping dock's airfreight schedule, manpower availability, all will be available to complete the order. Even finding where the order is at any point should take anyone with access to the system only a few keystrokes. With appropriate logons and web hosting, the customer can have his own visibility into the process, with each

company deciding what level of access to grant. Some ERP applications can even extend that same level of magic to other major processes like personnel and finances.

Employee Empowerment. With ERP, virtually everyone in the company with a keyboard and terminal is elevated to a level of information access formerly available to a select few; the corporate structure is flattened and broadened. The customer representative on the loading dock has access to the customer's ratings from the finance department and production levels from the factory floor. Information that used to be tracked in the warehouse on a few scraps of paper, or in someone's head, will now need to be entered into the database.

Customer Relationship Management (CRM). One of ERP's key metrics is a closer link between customer and the manufacturer or supplier, which results in a shorter fulfillment time with a highly customized product. Unfortunately, this has proven to be a real challenge. SAP originated in Germany, a country that in a recent study came in dead last in CRM in the areas of analysis and planning, performance review, and information and technology, all key areas in ERP.[xxxviii] A second study indicated that customers in Germany were rarely dealt with on a personal level. Particularly frustrating for them was their e-mails went unanswered, and that they couldn't find what they were shopping for. This study, "Technology Compass 2006: The Future of CRM Technologies and Applications", reported that of the 175,000 buyers that surf the Internet every day, an estimated 75 percent won't place an order. Two or three times every three months, an online shopper will leave a "full shopping cart" without being encouraged to stay and complete the sale.[xxxix] Even a service-providing organization can't afford to let interested "shoppers" walk away, leaving full carts behind.

Vendor-Managed Inventory (VMI). It often comes as a shock to tier 2, tier 3 and lower suppliers when a company they work with tells them that they are now going to have on-line inventory management. This equates to a shift to a vendor-managed inventory. Part of the shock comes from the sense that the supplier would now be responsible for another company's inventory. The fear extends to thinking that if inventory levels are misread, the supplier could be held responsible for shutting down an entire automobile plant, or other large, supplier-dependent manufacturer.

ERP and Six-Sigma. While ERP may be as close as this decade will come to seeing a revolution in the way manufacturing does business, it's a slow process. Since it focuses primarily on optimizing internal processes it has many similarities with the processes of Six Sigma. Six Sigma and ERP are top-down, top-*driven* events, so the CEO and CIO must get involved for the process to succeed.

Web Hosting. The goal of a full scale ERP system is typically to pull together the top-level business functions from human resources and financials to supply chain management and the manufacturing floor. However, the month to years-long process, frequently costing many millions of dollars, can put the benefits of ERP out of reach for tier 2, 3 or 4 suppliers and smaller businesses.

With the advent of the Internet and browser-based technologies, small-to-medium companies are beginning to realize many of the advantages found in a full ERP implementation, yet within a price range that won't make the CFO cringe. The notion of using Web technologies to utilize ERP solutions across a business on a monthly rental basis is beginning to attract interest.[xl]

ERP's Hidden True Costs. Training is a pernicious cost because it's so easy to underestimate. Part of this comes from the fact that workers not only have to learn how to navigate the new software; they also have to learn new business processes.

Integration and testing is difficult to measure because every company orders up a different suite of applications and may even get several different vendors software. In the Advanced Manufacturing Seminar's studies in Japan, companies are creating their own quasi-ERP applications from a combination of database software and cobbled-together legacy software systems. While this creates a highly customized system, the costs of integrating, testing and maintaining the system can be expected to skyrocket.[xli]

Data conversion from legacy systems can be an awesome undertaking. An order that's seemingly self-evident when jotted on an order pad can take a maddeningly long time to quantify for a common database. An ERP system integration expert at a U.S. consultancy firm revealed that this conversion is so frustrating because most of the information in legacy systems is "dirty" and unusable in the new system.

Data analysis runs up costs because most ERP systems do a poor job of indicating which information is changing from day to day, and refreshing the data in a big corporate data "warehouse" daily is difficult. Custom programming can solve this, but it brings the expense loop full circle because it's expensive and difficult to keep updated.

Loss of the best and brightest personnel is hard to prepare for or prevent. The first loss is when project personnel are pulled from their regular jobs to fire up the new ERP system. Once they get all this valuable ERP operation and installation information, they'll know more about the business than most sales and management personnel combined. This makes them extremely valuable to competitors, and to other companies facing a similarly daunting ERP integration.[xlii] It's not unusual to have headhunters come knocking at the team's door. The long lead-time for positive results makes the headhunters offers of double and triple salary hard to resist, and internal resistance and negative feedback make it easy to leave. The ones that stay become truly invaluable. "The [team members] who stayed are driving the company now because they have the functional knowledge *and* the system knowledge [emphasis added]."[xliii]

Post-installation effectiveness drop may be the most nerve wracking hidden cost of an ERP installation. After spending hundreds of thousands, perhaps millions, of dollars, it's reasonable to expect some return. Unfortunately, in a 1999 Deloitte Consulting survey of 64 Fortune 500 companies, fully 25% reported a significant drop in business performance lasting from three to nine months. The most common reported problem was that "…everything looks and works differently from how it did before. When people can't do their jobs in a familiar way and haven't yet mastered the new way, they panic, and the business goes into spasms."[xliv]

When Nestlé made its expensive ERP implementation, the…"primary lesson [Nestlé] says [it] has taken away from the project is this: No major software implementation is really about the software. It's about change management. 'If you weren't concerned with how the business ran, you could probably [install the ERP software] in 18 to 24 months,' says [Nestlé U.S.A CIO Jeri Dunn]. Then 'you would probably be in the unemployment line in 19 to 25 months.'" Nestlé learned the hard way that an enterprise-wide rollout involves much more than simply installing software. "When you move to SAP, you are changing the way people work," Dunn says. "You are challenging their principles, their beliefs and the way they have done things for many, many years."[xlv]

Time investment for report preparation takes a heavy toll on ERP systems and the operators. The sheer volume of information available makes the system a tempting target. Adding to the feeling of urgency is that nothing looks or works quite the way it did before. However, the emotional and reporting need for the reports and information that "always used to be there" means there will be a heavy load on the new system. Plus, for the first time, hundreds to

thousands of employees around the U.S.A and around the world will be pulling information from the ERP system's single, integrated database. All those reports clog up the system as large numbers of employees are trying to simultaneously make data entries and retrieve information. It's reported that this is the number one fire that the ERP team will be spending its time to put out.

Keys to Success? There do seem to be a few commonalties in the companies that have made ERP work, despite the daunting challenges of cost, time and resistance to change. Implementing an ERP system isn't about the software because that's a relatively easy process. The hard part is mingling the old with the new, and especially, changing the daily business processes of the people who will use the system.

Software Bridging enables a new ERP system to be able to "talk" to the legacy systems. FedEx's ERP implementation team built a software bridge so that their old financial systems, developed over 20 years, could still operate for an interim period, aiming for a phase-out over a period of months. While this may be a workable solution, it's not a perfect or permanent one. Too many bridges slow the software processes. Hasbro Inc. built local practices into their ERP system that services eight countries, but it added layers of code to each country's transactions and made for slow response times.[xlvi]

Involvement by key stakeholders greatly reduces internal resistance; skipping this step can be fatal for CEO's, CIO's and the project. Nobody likes change in "the way we've always done things" or changes in what have become comfortably cumbersome processes…especially when they don't know it's coming. Nestlé found this out the hard way. None of the groups at Nestlé that were going to be directly affected by the new ERP processes and systems were represented on the key stakeholders team. Consequently, Nestlé U.S.A CEO Dunn said, "We were always surprising [the heads of sales and the divisions] because we would bring something up to the executive steering committee that they weren't privy to." Dunn called that her near fatal mistake.[xlvii]

Keeping customers involved has been a vital tool for many. They not only let customers know what is going on internally, they also use their customers as a source of advice, feedback and buy-in.

Engaging a proven and reputable solutions provider or consultant(s) has allowed companies to concentrate on their core worth and use fewer of their own valuable employees for system integration.

Ensuring full system integration is an easy step to overlook in a far-flung enterprise. Even though all purchasing departments may now have common names and terms, those names may not have been shared with financial, planning or sales groups. This may be especially true if the key stakeholders haven't been involved. Nestlé made this mistake, and found that a salesperson's discount to a valued customer was showing up in accounts receivable as being a partially paid bill. Problems like this and other integration problems became so severe that Nestlé ended up scrapping one ERP system part-way though implementation, and switched to another system. This added significantly to their over $200 million dollar ERP bill.[xlviii]

Information Management and Assurance. An Accenture study found, "With IT-enabled products that interact across open platforms and provide new opportunities, the solutions may be more valuable to the customer than the product itself."[xlix] Web hosting and information technologies are critical to business success, but also bring new vulnerabilities. When ideas (the solutions) become more valuable than the products, then the actual product being sold is the idea.

Keeping as nebulous a product as intellectual property safeguarded will be an enormous undertaking.

Many small and medium-size businesses are turning to easy to access, do-business-right-out-of-the-box commerce server systems. The installation's quick, relatively inexpensive and user-friendly. Unfortunately, there's a common downside: the security features are weak. A website devoted to information assurance, http://www.alldas.org, lists the most recent website defacements. A quick review shows that despite Microsoft Window's universality and hacker's oft-expressed disdain for "Mister Softee", Linux gets a surprisingly lopsided number of attacks. What does this mean? If you have a Web presence, whatever your size, expect to get attacked.

Interconnectivity: the solution is the problem, and the problem is the solution. As advanced manufacturers put more and more of their business on the Web, everyone and everything will be spending more time online. The biggest reason is cost and the second reason is the ease of connectivity, using enterprise resource planning systems. The potential is there to achieve manufacturing's Nirvana of being able to run a factory around the clock, without human intervention, with infinitely variable customer input directly to the machine making the finished good, with total tracking directly to the customer's door. However, every new window into the process opens a new chance for vulnerability. All threats to a company's cyber-security will have to be dealt with as if a business's life is a stake…because it is. Website visitors will have to be invited, cared for, managed and supervised adroitly, as if the company's business life is a stake…because it is.

ERP is expensive, but the payoff can be enormous. Full system integration takes a long time, but the resulting increased efficiency, positive results from company self-examination, boosted customer satisfaction, added value, reduced order wait times and better response to a changing market are required to stay competitive in the global arena. ERP isn't a panacea, but a properly selected, customized, fully integrated, tuned and maintained system working in concert with a well trained and empowered workforce, will be an extraordinarily powerful engine to pull corporations into the next decade.

HUMAN RESOURCES by LTC William N. Patterson

INTRODUCTION. As the manufacturing business world has grown increasingly competitive and global, companies have begun to look at employees in a different light. Even in the midst of technological advances, employees are still considered invaluable contributors and continue to be the single most important asset within the manufacturing industry. Now that labor typically represents anywhere from 35 to 55 percent of a company's operating cost, most organizations are faced with the daunting task of efficient labor management. [1] Organizations in the manufacturing arena continue to face new human resource challenges every day. They may range from dealing with labor unions to issues pertaining to rightsizing and the aging workforce. Yet 80% of manufacturers report a moderate to severe shortage of *qualified* job candidates as their number one concern. This is in spite of a recession in manufacturing and an economic downturn overall. The most serious workforce shortages are in production areas ranging from entry level workers, operators, machinists and craft workers to technicians and engineers. Even with the vast number of layoffs in the last six months, manufacturers find themselves scrambling for workers with certain skills.

While facing these challenges, manufacturing organizations must consistently harness the talent and energy of their human capital in order to achieve their bottom line objectives and maintain their competitive advantage. The problem, however, is exacerbated by the perception among the general public -- and, in particular, educators and their students -- that manufacturing takes place in dark, dirty, smoky environments. This could not be further from the truth. Manufacturing has taken on a totally different image. It now takes place in clean work areas, pharmaceutical laboratories, and brightly lit, clean, environmentally friendly production facilities employing advanced automation, robotics, and information technology.

Skill Shortage Issues. Even in the midst of a manufacturing recession and despite widespread layoffs, the industry continues to face a skilled worker shortage. A majority of manufacturers surveyed report finding qualified job applicants as their number one concern.[1i] Emphasis must be placed on the term "qualified." The advances in technology and overall change in the manufacturing arena, has made even entry level jobs a challenge for those without the proper education. This is particularly true for production jobs. One of the key problems is basic employability skills such as timeliness, work ethic and basic skills such as reading, writing and arithmetic. Manufacturers blame the school system for failing to properly prepare students for the workplace. These alarming deficiencies in fundamental skills are a direct reflection of the demographic realities of the tight labor market. Basically, there is a growing need for more collaboration between the private sector and government. Education reforms initiated by Congress will hopefully address these key issues, but implementation will be key.

Part of the problem is the diversity of U.S. manufacturing. Unlike some economies, which have only a narrow range of industries, the United States enjoys a manufacturing base that goes from potato chips to silicon chips, producing an amazing array of goods that range from steel to computers to luxury goods. While this diversity in manufacturing is undoubtedly good for the economy, it often makes manufacturing appear too broad a career for some to comprehend.

The other part of the problem, however, is manufacturers themselves. For all their worry about skills gaps and labor shortages, most U.S. manufacturers don't make much of an effort to educate their communities or even their own employees about the importance of manufacturing to the national and regional economies -- or how a skills gap could threaten U.S. competitiveness and, ultimately, its standard of living. Consequently, there are those who still see manufacturing jobs in a negative sense and fewer people are willing to enter the field, while more current employees are heading toward retirement.

Layoffs. More than 426,000 layoffs have been announced in the manufacturing sector since September 11. Manufacturing jobs are important to a nation's economy because for every person working in manufacturing there are several others working to support their work. November 2001 was the sixteenth consecutive month of manufacturing job loss. Since July 2000 manufacturing has lost 1.5 million jobs, and manufacturing employment has fallen to levels last seen in November 1965. Layoffs among durable goods manufacturers were most prevalent in transportation equipment and industrial equipment. Among nondurable-goods manufacturers, numbers of layoffs were highest in food and in apparel.

Demographic Trends (Aging Workforce). Another key concern of manufacturing managers is the ever-increasing age of the workforce. The number of "older" members remaining in the workforce continues to grow (see figure 1). The trend toward early retirement is beginning to reverse itself. Many of these "older" members believe that their education will allow them to continue to make a positive contribution within the workplace. A new report by the General Accounting Office (GAO) provides a more complete picture of the aging of the workforce than has typically been provided. The report, "Older Workers: Demographic Trends Pose Challenges for Employers and Workers", reveals the occupations that will be hardest hit when the baby boomers start to retire. It also documents what employers are doing--and not yet doing--to cope with potential occupational shortages. This is particularly true in the manufacturing arena. Machinists, for example, are considered "the heartbeat of manufacturing." But the average machinist is in his late 50s, and the United States is training only one machinist for every five that are lost.

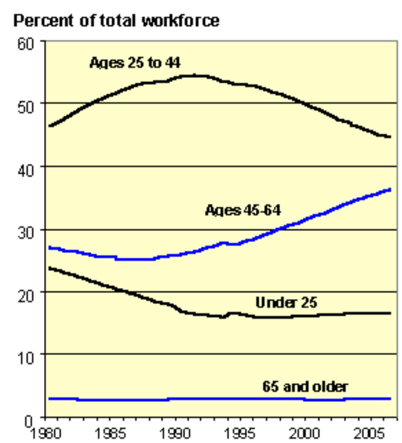

Fig. 1

Because the retirement of the baby boomer generation will occur gradually over the next several decades, there is still time available to develop sound policies, programs, and practices to respond to this demographic challenge. The significance of an aging workforce cannot be ignored. A wave of retirements looms before many employers, including some major

corporations. Unionized, manufacturing companies are likely to be most seriously affected. Many such companies downsized in the 1980s and early 1990s, and as the ax swung, workers with the greatest seniority typically kept their jobs. This is especially true in unionized organizations. Because only a minority of the downsizing companies subsequently hires many new production-line employees, their workforces are beginning to look positively geriatric.

What should a company do when it discovers that a large percentage of its workforce will soon be eligible for retirement? The first thing the firm can do is identify its "older-keepers." These are workers whose knowledge, skills, experience, and contacts are so valuable that the company cannot afford to lose them, even though they may be eligible for retirement. The company must find ways to retain them while it has time to find and prepare replacements. The next thing the company can do is change its workplace and compensation practices to make them more them more suited to older workers. Third, it can move quickly to recruit or prepare understudies for older workers who are ready for early retirement. Fourth, it can reengineer production processes, capital equipment, and even product mixes to operate with fewer workers. Finally, if all else fails, it can relocate production to a location where there is a more qualified workforce.

Additionally, the government has intervened to protect older workers. Two key pieces of legislation associated with "the aging workforce" are the Age Discrimination and Employment Act (ADEA) and the Older Workers Benefit and Protection Act (OWBPA). The Age Discrimination and Employment Act was enacted in 1967 to prohibit age discrimination in employment. The Older Worker's Benefits Protection Act (amendment to ADEA) allows for waivers to the ADEA and requires that any agreement to waive age discrimination claims meet certain strict criteria before it will be enforceable. Among other things, the agreement must advise the employee to seek advice of an attorney; must give the employee 21 days to consider the agreement before signing, as well as seven days to revoke the agreement; and must specifically state that the employee is releasing claims based on age discrimination.[lii]

Here are some other key labor trends regarding the manufacturing workforce through 2006:

- Total employment will grow to 144.7 million jobs by 2005.
- The U.S. will have to look to fill jobs abroad, once faced with a 2M worker shortage.
- The number of workers between the age of 55 and 64 will increase 54% between 1996 and 2006, while workers between 25 to 44 will only increase 8 % during the same period.
- Older workers who have seniority will survive downsizing and carry the balance of the workload (especially in the union shops).
- For older workers, chronic disease such as cancer is likely to be prevalent.
- The rate at which women will join the workforce will be twice the rate of men.

- Seventy-three percent of single women who must balance responsibilities with little or no outside support
- An increasing number of women and single parents will lead the workplace revolution.
- Due to improvements in technology and the changing nature of work, the number of telecommuters will increase dramatically.[liii]

Conclusion. Manufacturing continues to be by far the largest of the goods-producing industries in terms of employment. While factories account for just a little more than a third of goods-producing establishments, manufacturing employees outnumber their colleagues in construction and mining by nearly 3-to-1. The shortage of skilled workers continues to be the single greatest concern of manufacturing leadership. Some key facts to remember about the manufacturing industry are:

1. An aging workforce – average age of a skilled manufacturing worker nationwide is 40.1.
2. According to current statistics, 40% of the nation's workforce will retire within 5 years.
3. The perception is that manufacturing jobs are dangerous dirty work. The reality is vastly different. Many of today's manufacturing plants are cleaner than most operating rooms.
4. While manufacturing may not be considered "high tech," computer literacy is definitely needed to run state-of-the-art equipment in most facilities.
5. There is still the lingering belief that manufacturing does not provide stability and that glamorous high-tech jobs will provide both big money and rapid career advancement.

What does all this mean? Manufacturing will survive all the harsh realities of the new technological world of globalization. Training and education will be the key. Layoffs because of downsizing will in all likelihood continue. The workforce will continue to age; therefore, management must bring in new employees and position them to replace members of the aging workforce.

Fluidic Self Assembly - Innovative Manufacturing Technology

by Mr. Kerry Kachejian - Raytheon

INTRODUCTION. Flexible manufacturing processes are needed that can provide the Department of Defense (DoD) with assured access to affordable, customized electronic systems. Without these advanced manufacturing processes, many next generation warfighting systems will risk being crippled or cancelled due to major cost and schedule overruns. Flexible processes are central to the success of acquisition reform, as they will encourage more suppliers to compete for specialized DoD business. Flexible manufacturing will also enable the mass customization of products and create new market opportunities in the commercial sector. One of the most promising flexible manufacturing approaches is Fluidic Self Assembly (FSA™). FSA can provide DoD with assured access to affordable, customized electronic systems.

BACKGROUND. The current DoD electronics market is relatively small and specialized, requiring low-volume production. High-volume commercial fabrication facilities lack the agility and motivation to adapt their lines to handle a small DoD production run. Military electronics are considered a niche market and given a low priority, especially during peacetime. Only a few contractors compete in the military electronics market, and these companies cannot achieve the cost efficiencies realized by high-volume manufacturers.

Acquisition reform has led DoD to pursue high-volume commercial-off-the-shelf (COTS) electronics for many of its needs. COTS offers the military both low cost and quick access to components. For many DoD applications where performance, space, weight and shape are not critical, COTS is a smart way to reduce development and production costs.

However, the real DoD challenge is getting low-cost and timely access to specialized, low-density electronic components. Many of the next generation warfighting systems will depend on customized electronics because they are space, weight, and shape constrained. These new platforms include stealth aircraft, robotic vehicles (air, land, sea and underwater) and objective force warriors. These emerging DoD systems will require small phased array radars, conformal sensors and antennas, radio frequency ID (RFID) tags, wearable computers, and advanced displays to provide the military with a competitive edge. Flexible manufacturing systems are needed that can satisfy DoD production requirements.

FLUIDIC SELF ASSEMBLY (FSA™). Fluidic Self Assembly (FSA™) offers a new and revolutionary approach to electronics manufacturing. FSA offers low cost, customization and immediate access – key features needed to develop and support advanced DoD electronic systems. FSA is perhaps the most promising flexible manufacturing approach that can improve both the economic and military strength of the United States. Initial applications of the technology are for the manufacture of flat-panel displays (FPDs) and RFID tags. However, the potential impact is far more pervasive.

Technology Innovation. FSA assembles microscopic circuits (nanoblocks) onto a plastic film. The actual shape of each type of nanoblock varies, based on its individual function. The shape of a nanoblock matches that of a corresponding precision hole (receptor) in the substrate. Prior to assembly, all nanoblocks are fully tested and suspended in a fluid. The fluid provides a protective coating and aids the assembly process.

Thousands of suspended nanoblocks flow out of dispensing heads and over the substrate's surface where they self align and fill into a corresponding receptor hole. Thousands of nanoblocks can be assembled in a few seconds, making the process massively parallel. Using multiple dispensing heads and a CCD inspection ensures a 100% nanoblock assembly fill.

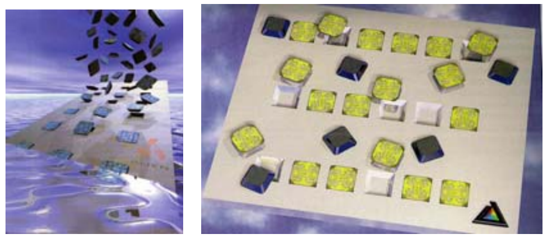

Figure 1. Nanoblocks fill into receptors

Unused nanoblocks are recycled. Re-use minimizes waste and makes self assembly an efficient process. Once all nanoblocks are deposited, a planarizing layer is applied. Next, nanoblocks are interconnected using conventional lithography and etching techniques.[liv]

<u>Why is FSA better?</u> FSA is cost effective due to the low capital cost of the equipment, the high yields (100% of substrate fills) and the high efficiency (100% nanoblock use).

FSA facilities are modular and upgradeable. They are an order of magnitude less expensive, removing a major barrier to market entry. For example, a flat-panel display plant costs about $600M, while a comparable FSA factory would cost only $60M.[lv]

High yields and a massively parallel process allow FSA to produce electronic systems at a fraction of their conventional cost. FSA can assemble products out of a continuous plastic sheet. Current pick-and-place assembly methods are far more expensive and time consuming.

Because FSA can use a flexible plastic substrate, products can be made conformal to many surfaces. For example, FSA can make flat panel displays out of a plastic sheet instead of glass, enabling the manufacture of displays that pull down like a window shade. Ultimately, FSA is a low-cost way to embed electronics in just about anything.[lvi]

Another benefit of FSA is its inherent compatibility with multiple substrates, semiconductor materials, integrated circuits (ICs), and MEMS devices. This design flexibility enables the production of a broad spectrum of highly capable customized products.

CONTRIBUTION TO NATIONAL SECURITY. Electronics manufacturing is a defense-essential industry, providing products that satisfy national security requirements during both peace and conflict. The electronic content of military systems is increasingly what provides the technological superiority of our forces. How well we maintain this competitive advantage will depend on how well we can assure timely, affordable access to electronics manufacturing facilities. FSA can make an important contribution to U.S. national security for many reasons:

<u>Assured Access</u>. Flat-panel displays (FPDs) are critical to many of our defense systems. However, the U.S. lacks a meaningful FPD industrial base, and is dependent on foreign sources. The main domestic supplier for ruggedized military displays, Planar Systems, is withdrawing from the market because it is unprofitable.[lvii] This leaves the U.S. military in a vulnerable position. FSA offers the U.S. the opportunity to re-enter the commercial and military FPD market. FSA displays have military application because they are lighter and more durable than glass displays.

<u>Reduced Acquisition Time</u>. FSA enables rapid prototyping and experimentation for advanced DoD electronic systems. This will help reduce the development time for new systems. In the words of Paul G. Kaminski, "Military advantage goes to the nation who has the best cycle time to capture technologies that are commercially available, incorporate them into our systems,

and get them fielded first."[lviii] Technology insertion also supports military transformation. Other benefits include reduced cost and increased productivity while improving quality and performance.

Surge Production. FSA facilities can provide surge production for critical electronic systems. The technology's relatively low entry cost, high flexibility, and massively parallel assembly process enable facilities to quickly respond to an increased production directive under the Defense Procurement Act (DPA). FSA also eases DoD's concern that 2nd and 3rd tier suppliers will cease production of key components resulting in "vanishing vendor items." FSA enables DoD to quickly identify and develop alternative suppliers.

Homeland Security. FSA can have a direct and pervasive impact on systems that protect our national security. For example, FSA offers a credible approach to producing RFID tags for only a few pennies. At this price, such tags could be widely used for tracking luggage, packages, and containers as they transit through and within our borders. These tags also have tremendous potential in supply chain management and controlling theft and counterfeiting, a problem that drains $200 billion annually from the U.S. economy.[lix] FSA can also provide a tamperproof approach for developing national ID cards or unifying drivers license procedures. These cards could also expedite the passage of frequent trusted passengers through our airports.[lx]

CHALLENGES. FSA offers much promise, but it has not yet transitioned into full-scale production. The transition of new technology from low volume assembly to full production usually presents significant technical challenges. FSA uses unique new equipment. To succeed, the process must satisfactorily demonstrate all of the fundamental "ilities": producibility, manufacturability, testability, availability, maintainability, and reliability.

FSA also faces several non-technical challenges. If FSA can affordably produce RFID tags, the real challenge to proliferation may be the lack of infrastructure. RFID tag readers need to be deployed and people need to be trained.[lxi] Furthermore, before FSA could be used to develop a national ID card, personal privacy policy issues will need to be resolved.

OUTLOOK. FSA is a breakthrough technology with sustainable advantages and scalable manufacturing processes.[lxii] The process can re-shape the manufacturing cost dynamics of the $40 billion display market. The licensing of FSA manufacturing techniques could unleash a wave of innovation and accelerate growth throughout the electronics industry.

Strategic investors are heavily investing in FSA recognizing its potential impact on electronic systems manufacturing, transportation, and logistics.[lxiii] GEMplus, the world's largest smart card maker, has recently awarded a $40 million production contract for simple FSA displays. This contract marks an important transition point for the technology. More advanced displays for pagers, cell phones and high-definition television screens are projected in the next few years.

Although initial FSA products are being shipped, profitability needs to be demonstrated before the technology will be widely adopted.

GOVERNMENT GOALS AND ROLES. Given FSA's current state of development and its relevance to U.S. national security, what are appropriate U.S. Government goals and roles? Clearly, the public sector should not allocate resources where the private sector is already investing. These areas include funding initial pilot lines or demonstrating incrementally improved products.

However, the Government should fund demonstrations of stressing military applications that accelerate the development FSA technology. These efforts are usually too expensive or too long term for any one company to attempt alone, but if available, would benefit the broader industry. Funding demonstrations of Government assured access to FSA production lines is also appropriate.

Other recommended public investments are efforts that quickly expand the industrial base by reducing barriers to FSA entry. For example, a government-owned / supported FSA facility could be made available to universities and defense contractors to encourage the adoption of the FSA process. Furthermore, funding short courses to educate acquisition officials, business leaders, and engineers is appropriate. These steps serve to accelerate infrastructure growth and worked well for the DARPA MEMS program a decade ago. Because this is a rapidly developing technology, the Government must maintain a continuous dialogue with industry to understand and coordinate when and where industry will invest.

CONCLUSION. Fluidic Self Assembly is a visionary approach to flexible electronics manufacturing that can make a major contribution to both the military and economic elements of our national power. FSA can provide DoD with assured access to affordable, customized electronic systems. Without such advanced manufacturing processes, many next generation warfighting systems will risk failure due to major cost and schedule overruns. By making appropriate public sector investments in FSA, DoD will enable its own successful transformation.

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